NATIONAL RADIO ASTRONOMY OBSERVATORY
CHARLOTTESVILLE, VIRGINIA

ELECTRONICS DIVISION INTERNAL REPORT NO. 266

327 MHz AND 610 MHz, LOW-NOISE, FET AMPLIFIERS

R. HARRIS AND W. LAKATOSH

JANUARY 1987

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327 MHZ AND 610 MHZ, LOW-NOISE, FET AMPLIFIERS

R. Harris and W. Lakatosh

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327 MHZ AND 610 MHZ, LOW-NOISE, FET AMPLIFIERS

R. Harris and W. Lakatosh

I. Introduction

This report describes the construction and testing of a low-noise (approximately 0.4 dB noise figure or 28K noise temperature) GASFET amplifier designed for room temperature operation. The amplifier is easy to construct, operates from a single +8 to +15 volt supply, and provides approximately 33 dB gain.

Simultaneous noise and power match at the input is achieved by utilization of feedback within the FET device. The power match requires that the output tank circuit of the first FET be tuned to a higher frequency than the frequency for best input match; this results in the gain peaking at a higher frequency than input match. A broadband output match is achieved with a built-in attenuator pad.

II. Initial Assembly

After fabricating the circuit board, certain precautions must be taken to reduce the possibility of oscillations due to ground loops on the surface of the board. Short lengths of #22 tinned-copper wire must be inserted through the seven .031" diameter holes in the circuit board. Solder both sides of the board and remove excess wire.

It is important throughout construction of this amplifier to use good quality 2% silver-bearing solder along with appropriate flux (see Parts List).

Mount the nine chip capacitors, carefully avoiding the application of excessive heat. The 680 pF chip capacitor for the MGF-1412 source bypass should be mounted with the capacitor's inner surface on a line with the outside etched surface on the board. This is illustrated on NRAO Drawing No. A53201M013, detail C. The 680 pF chip capacitor for source bypass of MGF-1402 should have the outside surface on a line with this etched surface (refer to detail C).

Next, mount all the D.C. bias components including the two R.F. chokes (L_1, L_2) which form a D.C. return on the amplifier input. Do not mount the source resistors, transistors, or inductors (L_3, L_4) at this point.

Place partially completed board into modified chassis (see NRAO Drawing Nos. A53201M001 and A53201M002). Do not mount input and output connectors or feed-thru bypass capacitor. Secure board to chassis rails using eight #2-56 screws. Cut center pin and Teflon on SMA connectors as shown on NRAO Drawing No. A53201M003, detail C.

Prepare inductors L_3 and L_4, referring to NRAO Drawing No. A53201M013. The input inductor L_3 is eight turns, #26 AWG, .150" diameter, approximately .155" long, formed as shown in detail A. It is very important to wind this inductor in

a counter-clockwise direction (CCW). Inductor L_4 consists of eight turns, #26 wire, .150 diameter, .155" long, formed as shown in detail B. This inductor must be wound in a clockwise direction (CW).

Prepare both transistors by cutting gate length to .050"; do not cut drain lead.

III. Final Assembly

Use one of the previously prepared MGF-1412 GASFET's and center the transistor body between the two 680 pF source bypass capacitors (C_2, C_3). Precut the source leads to allow a 50 to 100% overlap on the source bypass capacitors; then solder leads in place. Place toroid core (FB_1) on drain lead and position drain lead to expose approximately .130" of length. Solder in place. The toroid core may be fixed in place with a drop of GC Electronics Q-Dope, catalog #37-2.

Repeat above procedure using MGF-1402.

Place inductor L_1 into position assuring the coil is wound in a counter-clockwise direction; then solder in place. At this time source resistor R_1 may be soldered along with resistor R_6.

Inductor L_4 may now be mounted, assuring the coil is wound in a clockwise direction. Mount the inductor on an angle of approximately 45° with a line through the center of the two transistors (refer to NRAO Drawing No. A53201M013, detail C). This completes the amplifier assembly.

IV. Testing

A scalar network analyzer similar to the Wiltron Model 560A will be necessary for the next phase.

The object is to achieve a return loss greater than 15 dB over the band of interest. For NRAO's purposes, the passband was 312 to 342 MHz, and gain at mid-band was approximately 33 dB.

The tuning elements available are the gate inductors (L_3, L_4), the source resistors (R_1, R_6), and the position of the first-stage source bypass capacitors. Changing the center-to-center distance of C_2 and C_3 provides some variation in first-stage source inductance. The output attenuator, provided to terminate the second stage over a wide frequency range, can be used to set overall amplifier gain.

The gate inductors should be positioned close to the surface of the board. Coils can be compressed or expanded, and their position relative to the board surface can be varied while observing the return loss on the network analyzer.

If sufficient bandpass is difficult to attain, the source resistor may be adjusted to produce slightly lower gain and slightly more bandwidth. If necessary, the first-stage source inductance may be varied by readjusting the center-to-center distance of the source bypass capacitors.

After the desired return loss and gain characteristics have been achieved, the amplifier should be tested for any sign of high frequency oscillations.

The input should be terminated with approximately 20 cm sliding short. While varying the input source impedance, there should be no sign of instability. The amplifier should be stable at all phase angles, terminated or unterminated. The cover plate should be installed and securely fastened while testing.

The noise characteristics of this amplifier are rather broad. After proper return loss and gain characteristics are obtained, no attempt should be made to minimize noise temperature. The ultimate noise temperature is a function of the particular input transistor chosen.

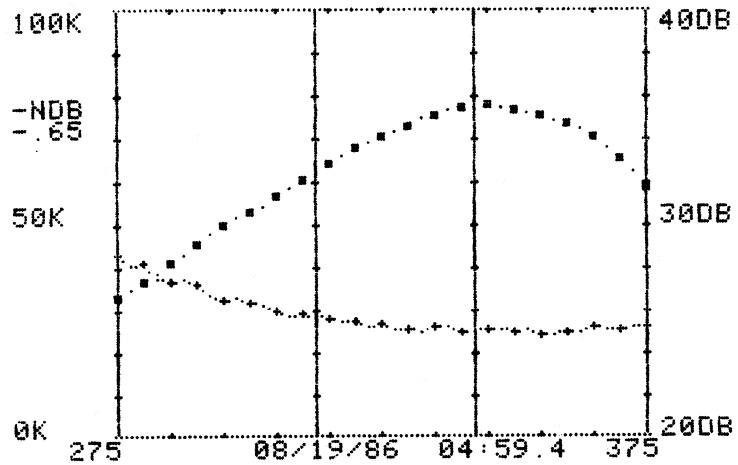
V. 610 MHz Amplifier

The materials and assembly procedures used for a 610 MHz amplifier are very similar to that used for the 327 MHz, low-noise, FET amplifier described here. The only changes required are to the input inductors L_3 and L_4 of the first and second stages; these are shown in attached drawings for both 327 MHz and 610 MHz. The gain, noise temperature, and input return loss for both frequencies are shown in Figures 1 and 2.

1) 327 MHZ. AMP. #41 ✂ 298K

Ø4:59.4 Ø8/19/86 TAV=26.1 TLO=24.4 @ 340 GL=32.4 GH=35.6 T=~~11K~~

~~Ø,Ø,1E-Ø3 Ø,Ø,1E-Ø3 Ø,Ø,1E-Ø3 Ø,Ø,1E-Ø3~~



Ø5:Ø1.Ø Ø8/19/86 ZERO=11.8 ADB=33 TF=298 -NDB=-.65

F,GHZ	NOISE	GAIN,DB	F,GHZ	NOISE	GAIN,DB
Ø.275	42.6	26.6	Ø.28	4Ø.6	27.3
Ø.285	36.7	28.1	Ø.29	35.8	29.1
Ø.295	32.Ø	29.9	Ø.3Ø	31.6	3Ø.5
Ø.3Ø5	29.9	31.3	Ø.31	28.8	32.Ø
Ø.315	27.9	32.8	Ø.32	27.Ø	33.5
Ø.325	26.3	34.1	Ø.33	25.3	34.5
Ø.335	25.9	35.1	Ø.34	24.4	35.5
Ø.345	25.4	35.5	Ø.35	24.5	35.3
Ø.355	24.4	35.1	Ø.36	24.9	34.7
Ø.365	25.9	34.Ø	Ø.37	25.1	33.1
Ø.375	26.1	31.7	Ø.38	Ø.Ø	Ø.Ø

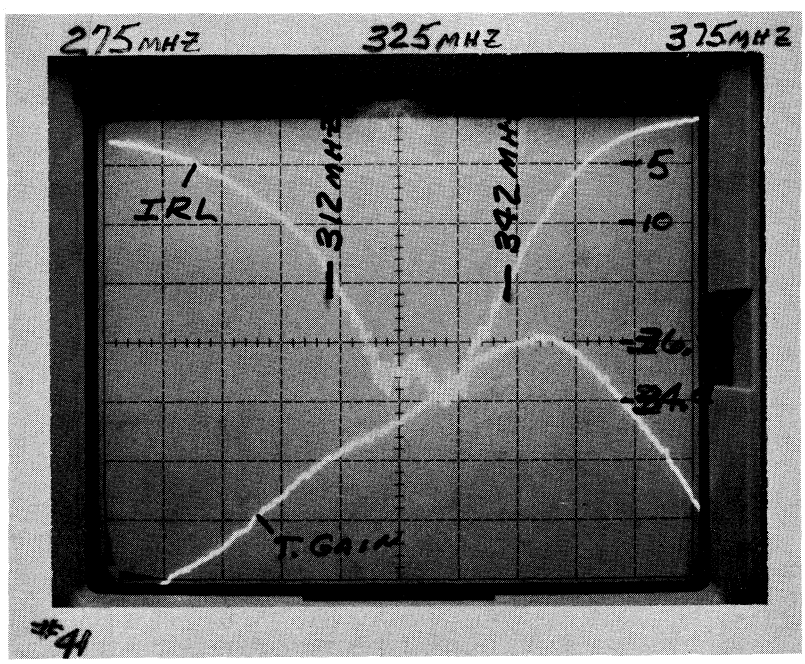
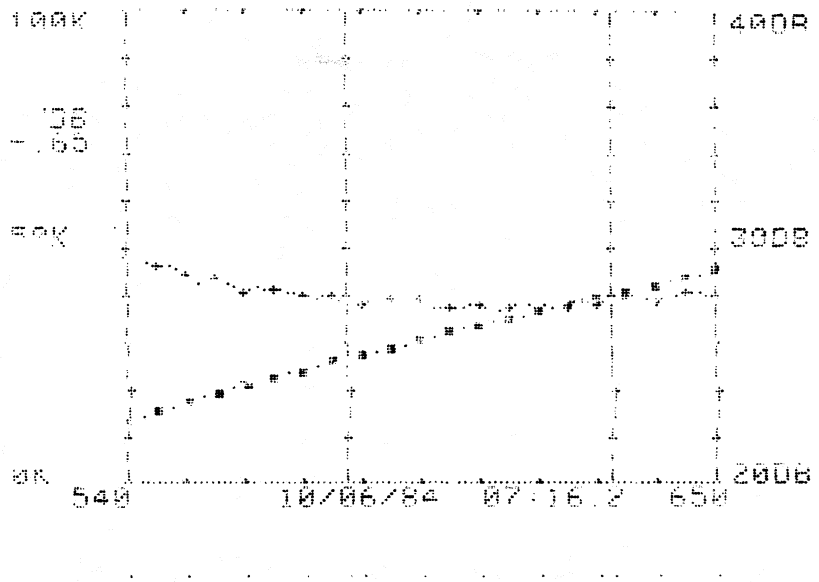


Fig. 1. Noise Temperature and Gain Characteristics of 327 MHz Amplifier.

300K

1) 610 PROTO USING 327 NOB
07:16.2 10/06/84 TAU=37.9 TLO=36 @ 608.75 GL=25.3 GH=27.9 T=-[illegible]K
-5.44. -10 -10,-100,-10 -10,-100,-10



07:20.5 10/06/84 ZERO=10.2 ADB=25 TF=300 -NDB=-.65

F,GHZ		GAIN,DB	F,GHZ	NOISE	GAIN,DB
.5675	40.9	24.5	.57025	40.6	24.7
.573		24.7	.57575	39.2	24.9
.5785	39.7	25.1	.58125	37.3	25.3
.584		25.4	.58675	38.7	25.6
.5895	38.8	25.7	.59225	38.2	25.9
.595		26	.59775	37.4	26.2
.6005	37.2	26.4	.60325	37.3	26.5
.606		26.7	.60875	36	26.9
.6115	37	27	.61425	38.4	27.1
.617		27.3	.61975	38.9	27.4
.6225	37.4	27.[illegible]	[illegible]	[illegible]	27.7

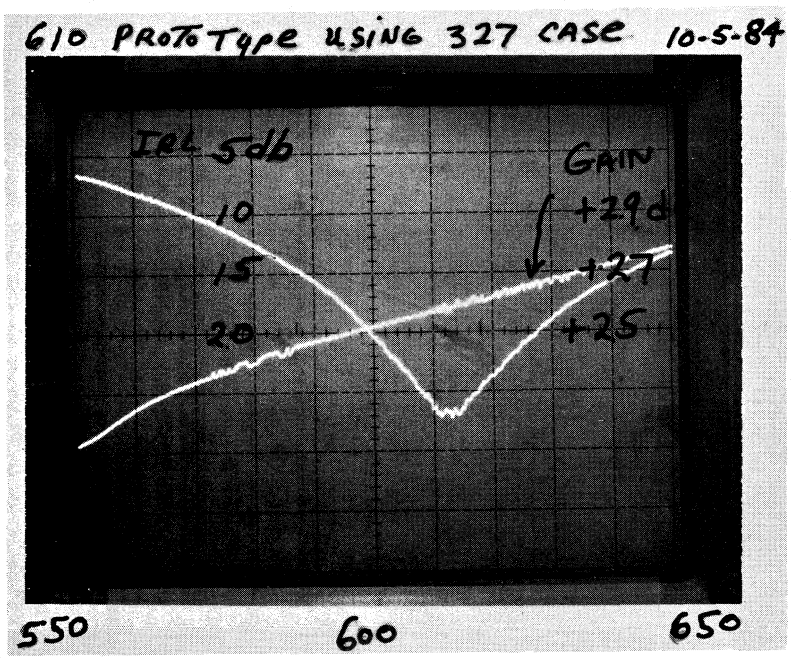
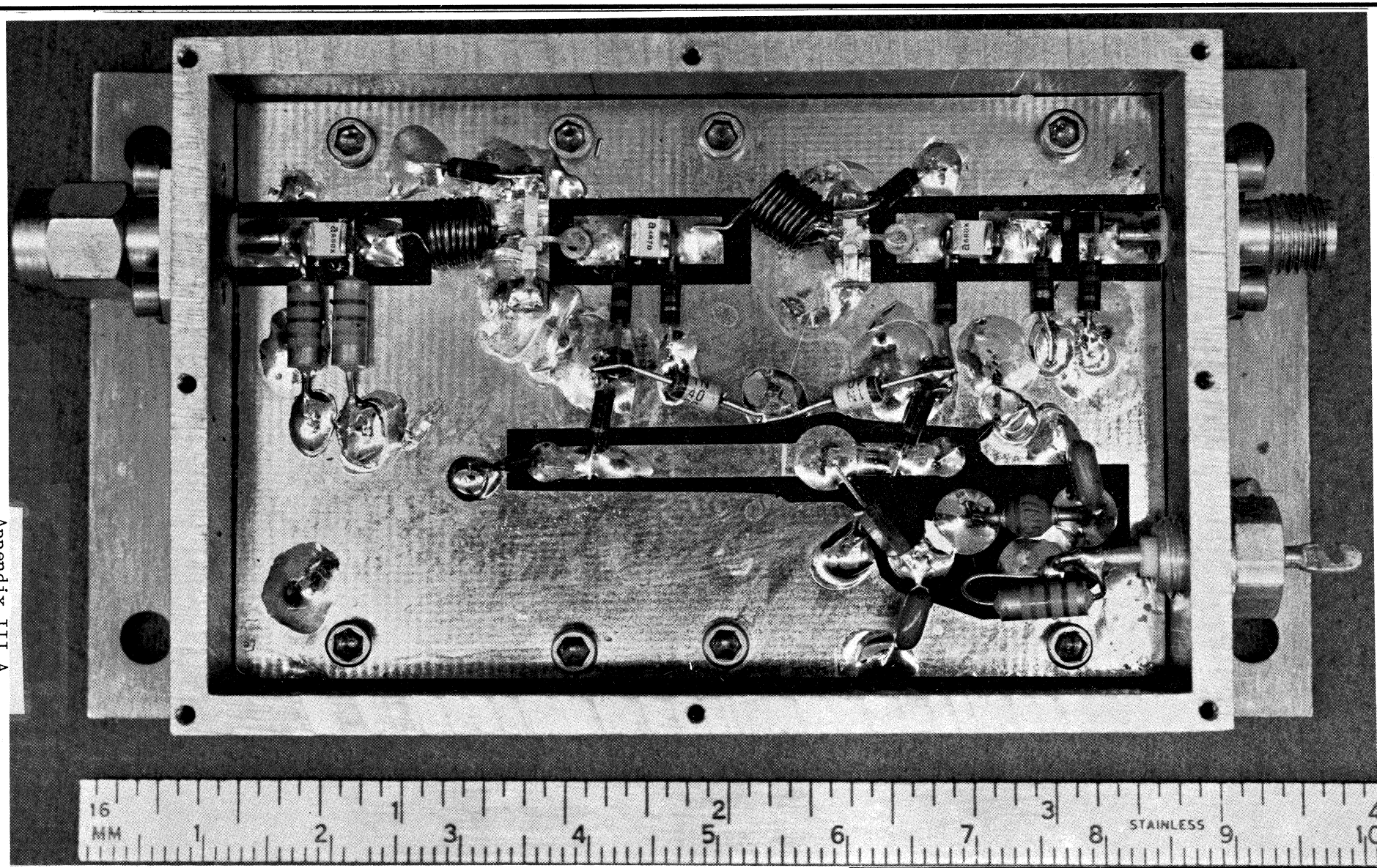
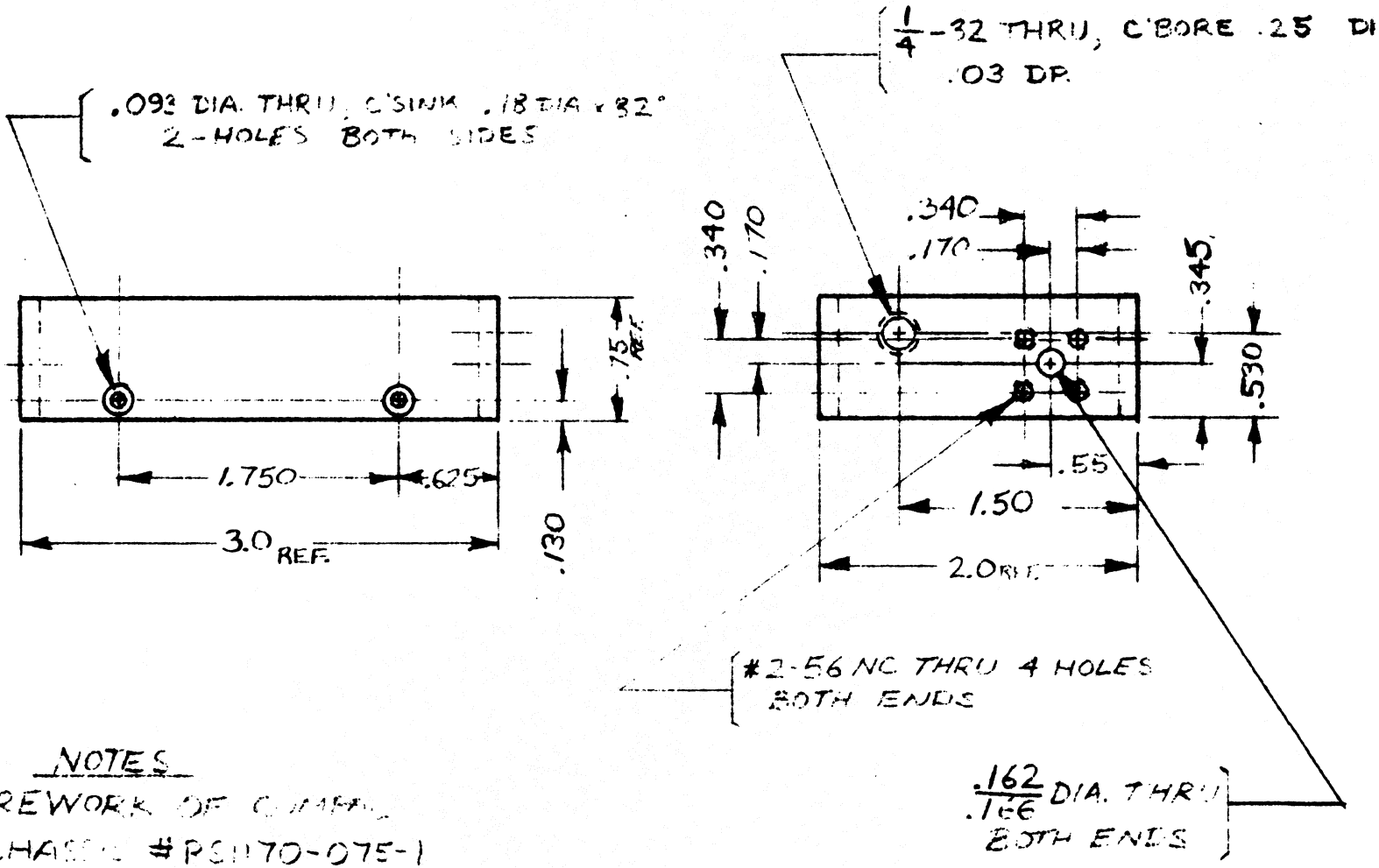


Fig. 2. Noise Temperature and Gain Characteristics of 610 MHz Amplifier.



NATIONAL RADIO ASTRONOMY OBSERVATORY VLBA			
PROJ: 327MHz FE	TITLE: AMPLIFIER ASSY		
MATERIAL:	DRAWN BY: BL		DATE: 12-86
	DESIGNED BY:		DATE:
FINISH:	APPROVED BY:		DATE:
SHEET NUMBER:	DRAWING NUMBER: A53201A003	REV.	SCALE:

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
3 PLACE DEC.(xxx) ±
2 PLACE DEC.(xx) ±
1 PLACE DEC. (x) ±



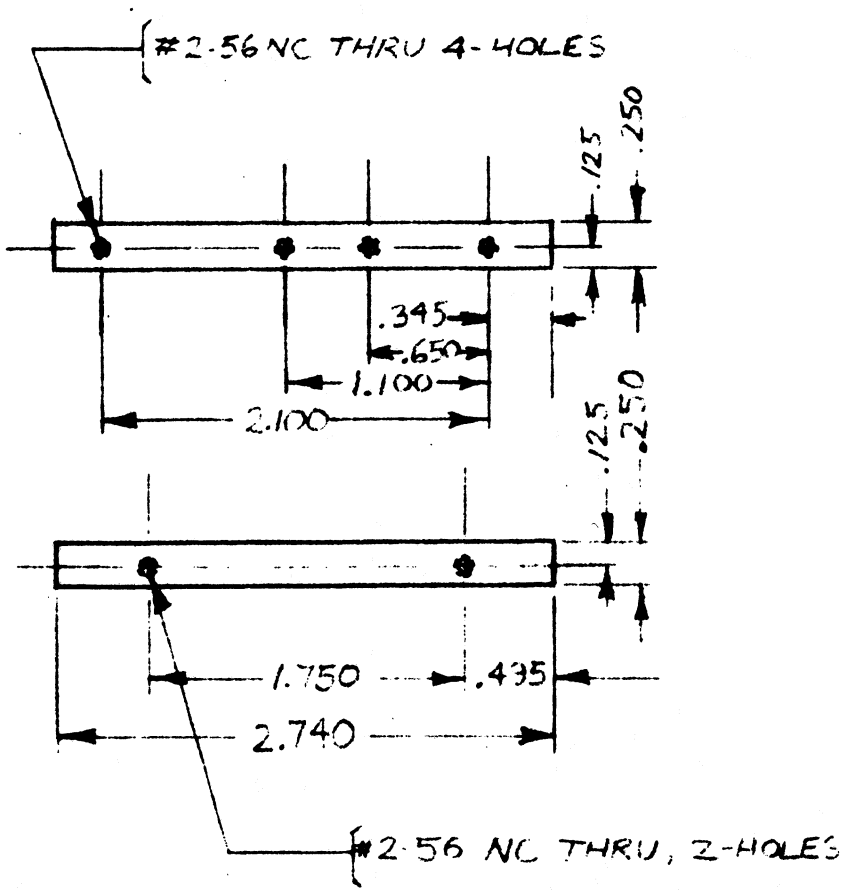
NOTES

1. REWORK OF CHASSIS #PS1170-075-1
2. DEBURR INSIDE EDGES OF CHASSIS.

NATIONAL RADIO ASTRONOMY OBSERVATORY VLBA			
PROJ: 327 MHz FE.	TITLE: 327 MHz CHASSIS		
MATERIAL: NOTE 1	DRAWN BY: H. DULL	DATE: 3/11/87	
FINISH: NONE	DESIGNED BY:	DATE:	
	APPROVED BY:	DATE:	
SHEET NUMBER:	DRAWING NUMBER: A53201M001	REV.	SCALE: FULL

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
3 PLACE DEC. (mm) ± .005
2 PLACE DEC. (in) ± .01
1 PLACE DEC. (in) ± .02

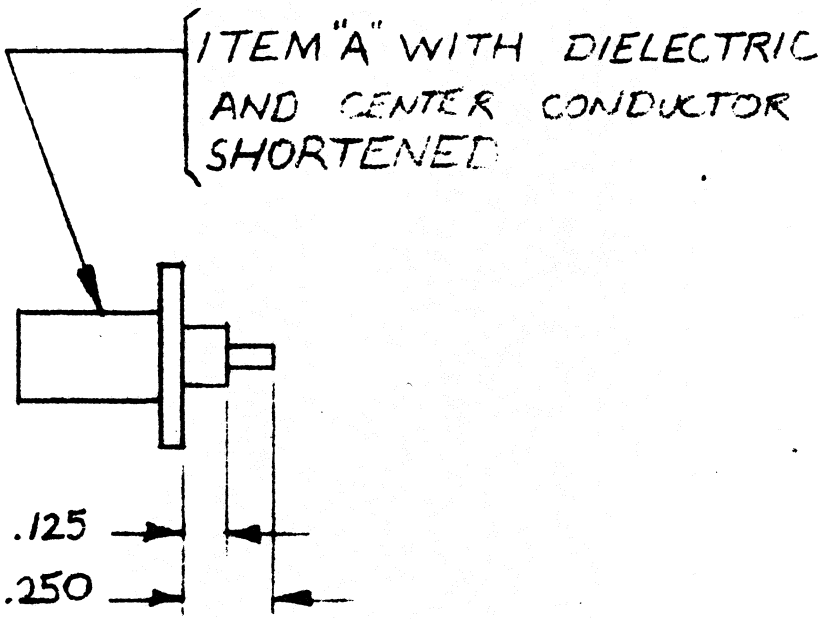
M.T. HALL



2 REQ

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES ± 3 PLACE DEC.(mm) ± 2 PLACE DEC.(m) ± 1 PLACE DEC. (in) ±	NATIONAL RADIO ASTRONOMY OBSERVATORY VLBA		
	PROJ: 327 MHz F.E	TITLE: RAIL	
	MATERIAL: ALUM	DRAWN BY: H DILL	DATE: 940911
	FINISH: ALODINE	DESIGNED BY:	DATE:
		APPROVED BY:	DATE:
	SHEET NUMBER: 1/1	DRAWING NUMBER: A53201M002	REV.
			SCALE: FULL

H. T. HALL



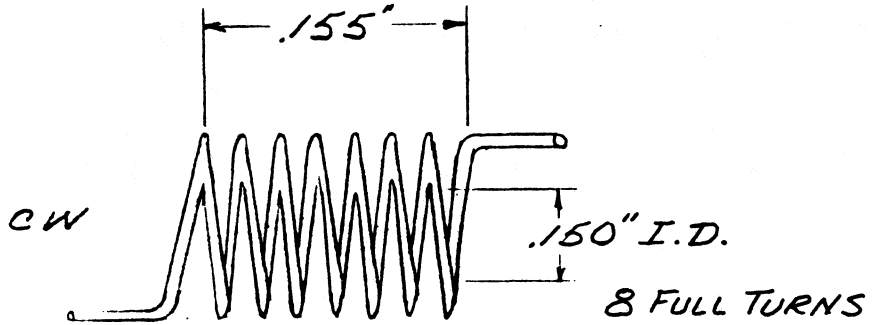
A53201M003-2	214 CC, PLUG (REF.)	1
A53201M003-1	204 CC, JACK (REF.)	1
PART #	ITEM "A"	QUAN.

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLBA

PROJ: 327 MHZ FE	TITLE: CONNECTOR, REWORK
MATERIAL: AS NOTED	DRAWN BY: H DILL
FINISH: NONE	DESIGNED BY:
	APPROVED BY:
SHEET NUMBER: 1:1	DRAWING NUMBER: A53201M003

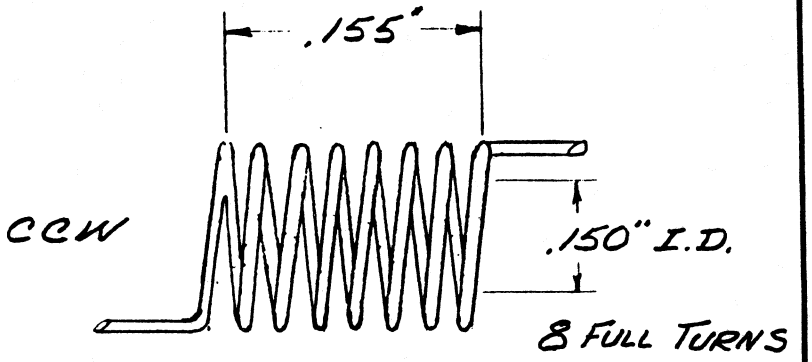
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
3 PLACE DEC. (mm) ± .005
2 PLACE DEC. (in.) ±
1 PLACE DEC. (in) ±

N.T. HALL



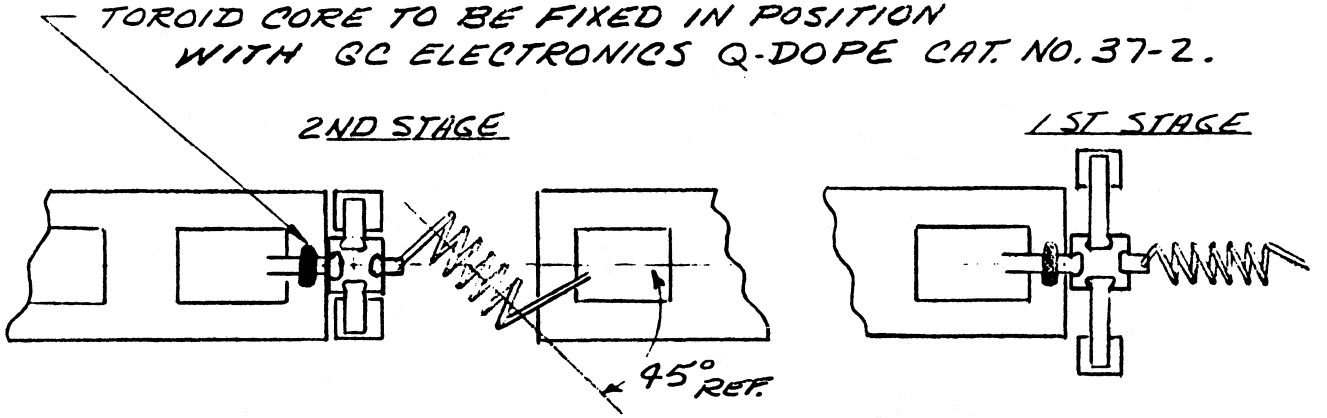
DETAIL B - 2ND STAGE

MATERIAL: #26 AWG ENAMEL



DETAIL A - 1ST STAGE

MATERIAL: #26 AWG ENAMEL



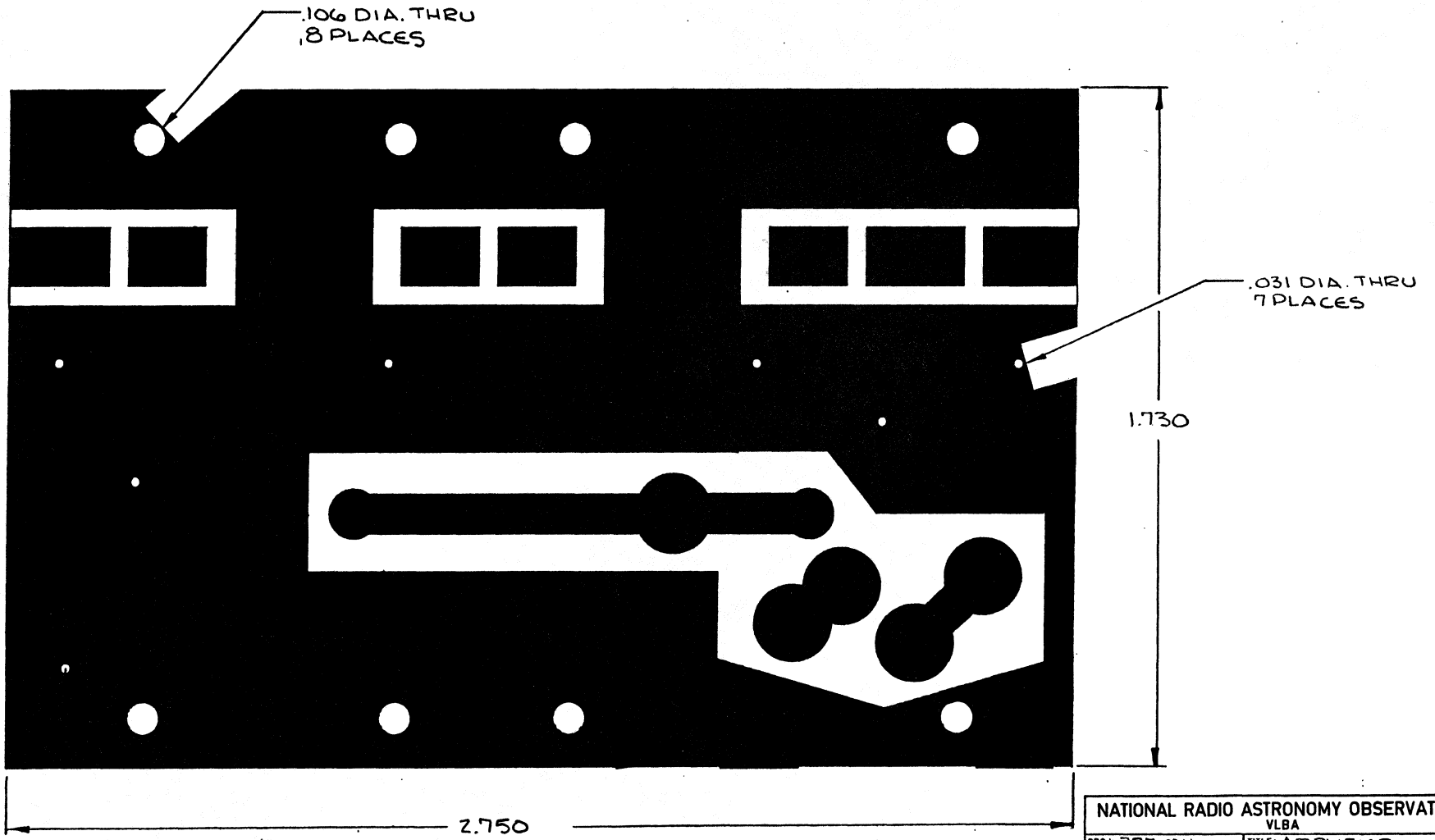
DETAIL C - COMPONENT LAYOUT

* NOT TO SCALE:

NATIONAL RADIO ASTRONOMY OBSERVATORY VLBA			
PROJ: 327 MHz FET.	TITLE: COMPONENT LAYOUT		
MATERIAL:	DRAWN BY: B. LAKATOS A	DATE: 10.21.82	
	DESIGNED BY:	DATE:	
FINISH:	APPROVED BY:	DATE:	
SHEET NUMBER:	DRAWING NUMBER: A53201M0013	REV.	SCALE: NONE

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
3 PLACE DEC. (xxx) ±
2 PLACE DEC. (xx) ±
1 PLACE DEC. (x) ±

H T HALL



NATIONAL RADIO ASTRONOMY OBSERVATORY VLBA			
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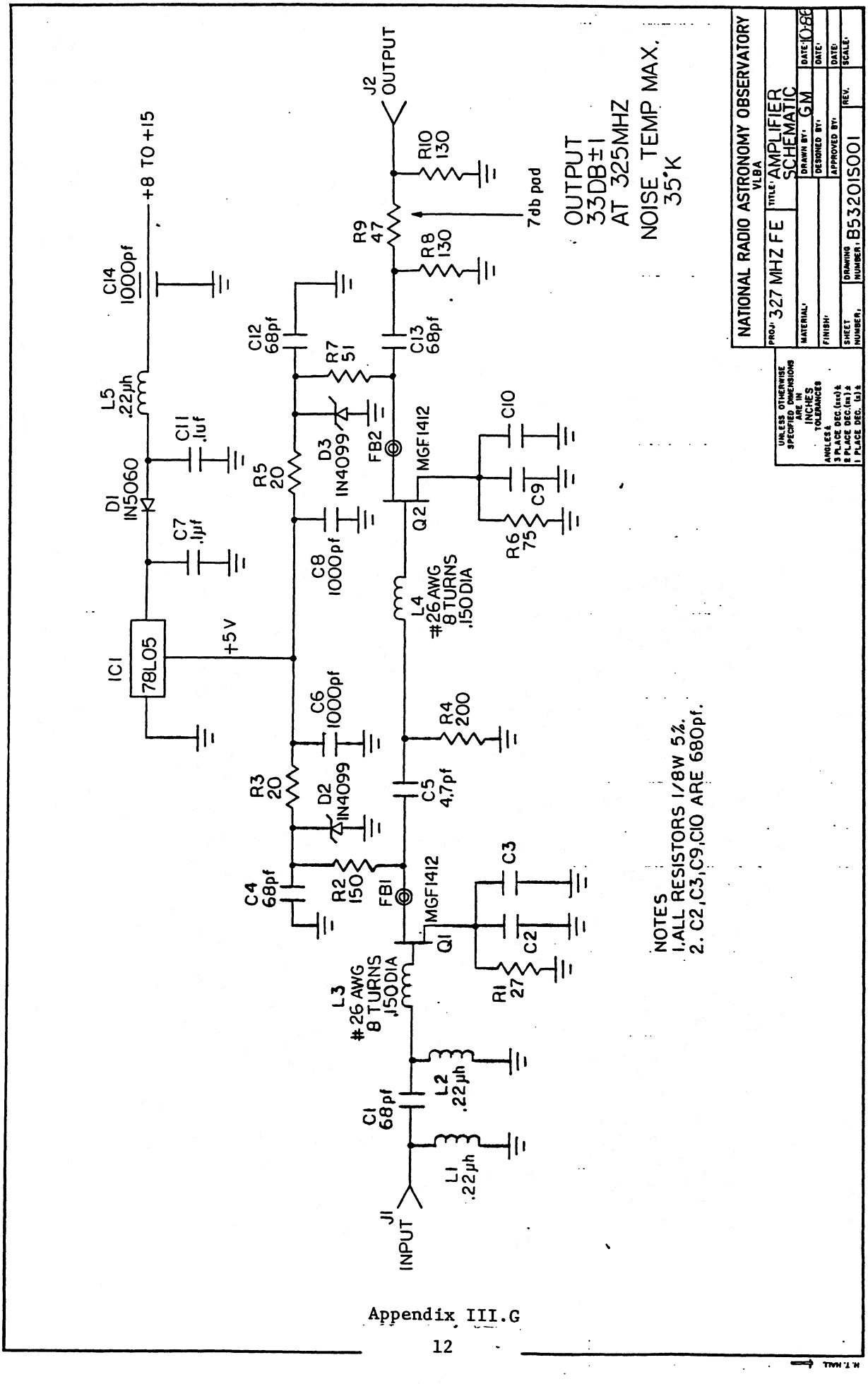
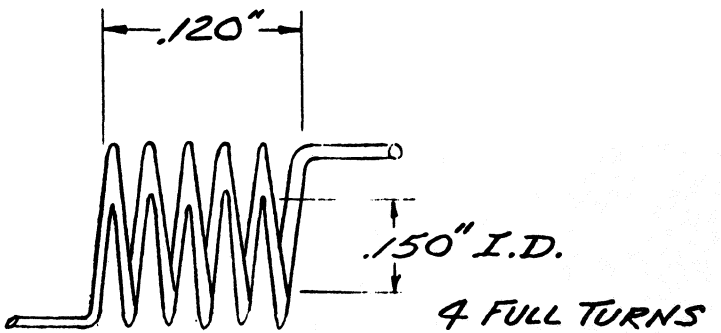
MATERIAL: .062 THK. G10 GLASS EPOXY	DRAWN BY: GM	DATE: 10-20-86	
FINISH:	DESIGNED BY:	DATE:	
	APPROVED BY:	DATE:	
SHEET NUMBER:	DRAWING NUMBER: B53201P001	REV.	SCALE: 4:1

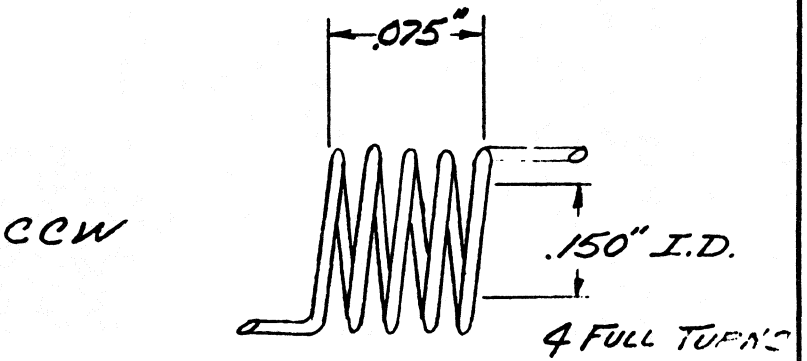
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
3 PLACE DEC. (xxx) ± .005
2 PLACE DEC. (xx) ±
1 PLACE DEC. (x) ±


NATIONAL RADIO ASTRONOMY OBSERVATORY
VLBA
PROJ: 327 MHZ FE
TITLE: AMPLIFIER SCHEMATIC
DRAWN BY: GM
DATE: 10/86
DESIGNED BY:
APPROVED BY:
SCALE:
DRAWING NUMBER: B5320ISOOI
REV.
MATERIAL:
FINISH:
SHEET NUMBER:
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
3 PLACE DEC. (xxx) ±
2 PLACE DEC. (xx) ±
1 PLACE DEC. (x) ±
J1 INPUT
J2 OUTPUT
+8 TO +15
+5 V
IC1 78L05
D1 IN5060
D2 IN4099
D3 IN4099
Q1 MGF1412
Q2 MGF1412
FB1
FB2
L1 .22µh
L2 .22µh
L3 #26 AWG 8 TURNS .150DIA
L4 #26 AWG 8 TURNS .150DIA
L5 .22µh
C1 68pf
C2
C3
C4 68pf
C5 4.7pf
C6 1000pf
C7 .1µf
C8 1000pf
C9
C10
C11 .1uf
C12 68pf
C13 68pf
C14 1000pf
R1 27
R2 150
R3 20
R4 200
R5 20
R6 75
R7 51
R8 130
R9 47
R10 130
7db pad
OUTPUT
33DB±1
AT 325MHZ
NOISE TEMP MAX.
35°K
NOTES
1. ALL RESISTORS 1/8W 5%.
2. C2,C3,C9,C10 ARE 680pf.



DETAIL B - 2ND STAGE

MATERIAL: #26 AWG ENAMEL



DETAIL A - 1ST STAGE

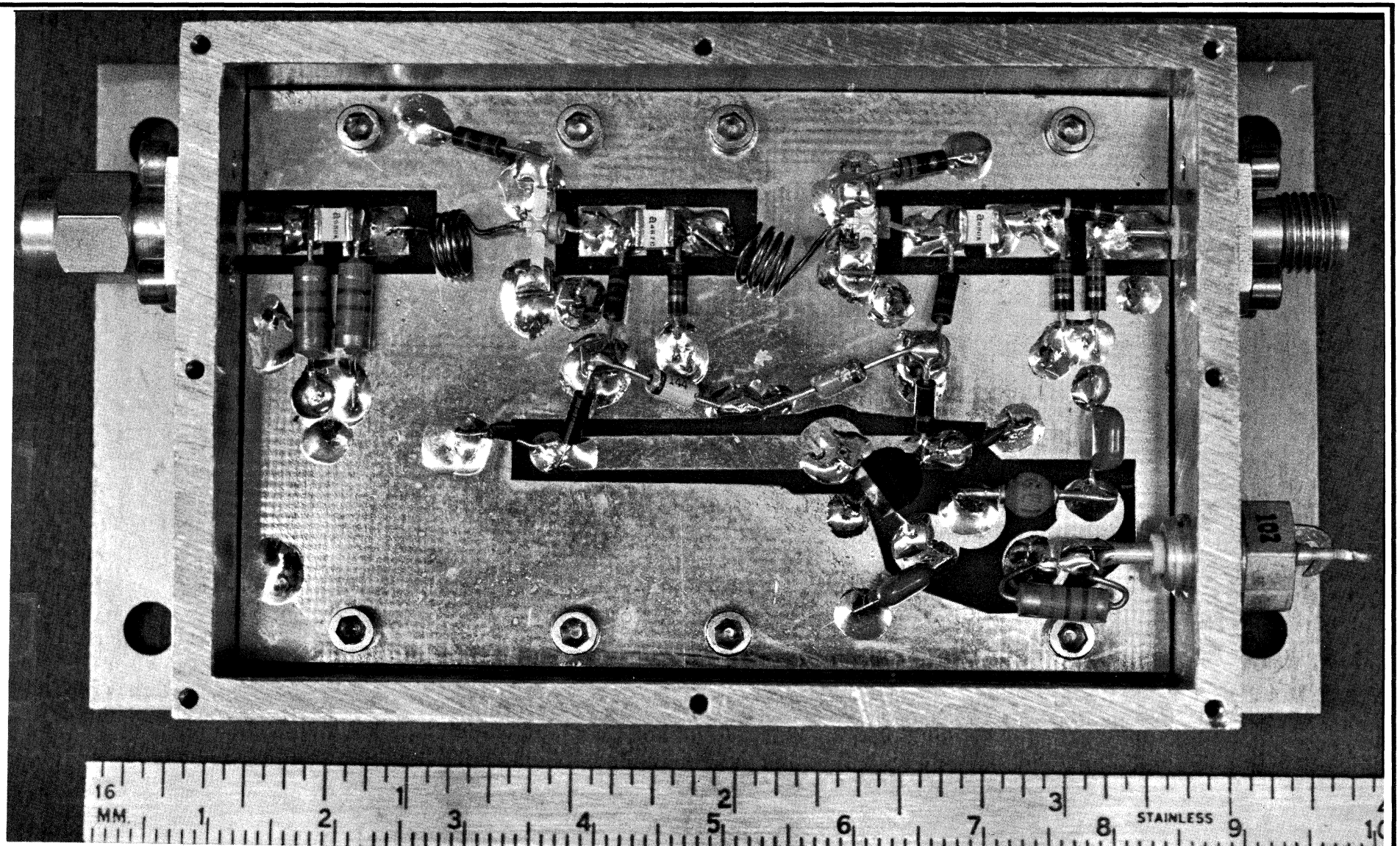
MATERIAL: #26 AWG ENAMEL

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
3 PLACE DEC. (xxx) ±
2 PLACE DEC. (xx) ±
1 PLACE DEC. (x) ±

NATIONAL RADIO ASTRONOMY OBSERVATORY
VLBA

PROJ: 610 MHZ. FET	TITLE: COMPONENTS		
MATERIAL:	DRAWN BY: B. LAKATOS	DATE: 11-17-	
	DESIGNED BY:	DATE:	
FINISH:	APPROVED BY:	DATE:	
SHEET NUMBER:	DRAWING NUMBER: A53201M014	REV.	SCALE: NONE

H. T. HALL



NATIONAL RADIO ASTRONOMY OBSERVATORY VLBA			
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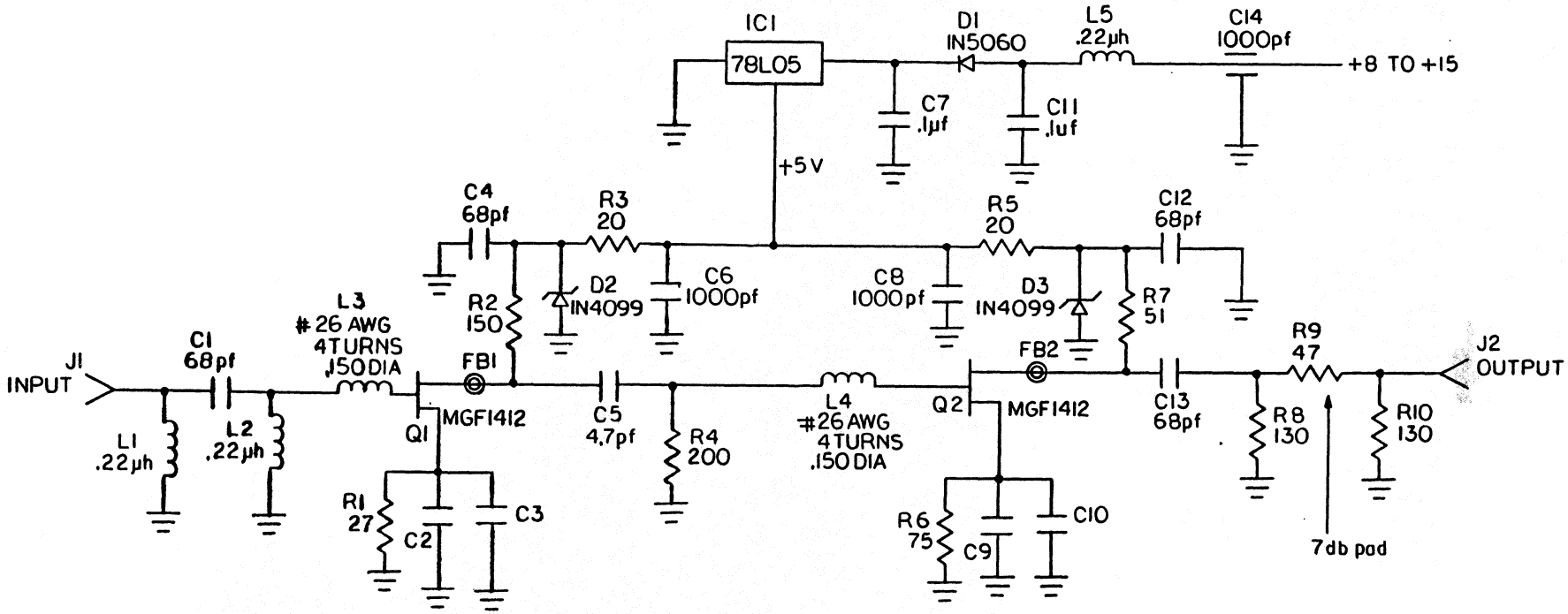
MATERIAL:	DRAWN BY: BL	DATE: 12-86	
	DESIGNED BY:	DATE:	
FINISH:	APPROVED BY:	DATE:	
SHEET NUMBER:	DRAWING NUMBER: A53202A003	REV.	SCALE:

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
3 PLACE DEC. (xxx) ±
2 PLACE DEC. (xx) ±
1 PLACE DEC. (x) ±

H. T. HALL



NOTES
1. ALL RESISTORS 1/8W 5%.
2. C2, C3, C9, C10 ARE 680pf.

NATIONAL RADIO ASTRONOMY OBSERVATORY VLBA			
PROJ: 610 MHZ FE	TITLE: AMPLIFIER SCHEMATIC		
MATERIAL:	DRAWN BY: GM	DATE: 10-86	
FINISH:	DESIGNED BY:	DATE:	
	APPROVED BY:	DATE:	
SHEET NUMBER:	DRAWING NUMBER: B53202S001	REV.	SCALE:

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES
ANGLES ±
3 PLACE DEC. (.xxx) ±
2 PLACE DEC. (.xx) ±
1 PLACE DEC. (.x) ±

PARTS LIST 327 MHZ., LOW NOISE, FET AMP. DATE 10-20-86 REVISION _____

SHEET 1 of 3

ITEM	QUANTITY	REF. DESIG.	DESCRIPTION	MFG.	PART NUMBER
1.	3	L_1, L_2, L_3	R.F. CHOKE, .22 u h	CAMBION	550-3399-05-02-00
2.	4	C_1, C_4, C_{12}, C_{13}	CHIP CAPACITOR, 68 PF., 100MIL.	ATC	ATC-100-B-680KP-500
3.	1	L_3	WIRE WOUND INDUCTOR	NRAO	A53201M013
4.	1	R_1	RESISTOR, CARBON COMP, 27Ω, 1/8W., 5%	ALLEN-BRADLEY	RC05GF270J
5.	4	C_2, C_3, C_9, C_{10}	CHIP CAPACITOR, 680 PF, 100MIL.	ATC	ATC-100-B-681-K-P
6.	1	Q_1	FET	MITSUBISHI	MGF-1412-11-08
7.	1	R_2	RESISTOR, CARBON COMP, 150Ω, 1/8W, 5%	ALLEN-BRADLEY	RC05GF151J
8.	1	C_5	CHIP CAPACITOR, 4.7 PF, 100MIL	ATC	ATC-100-B-4R7D-P500
9.	2	D_2, D_3	DIODE, ZENER	MOTOROLA	1N4099
10.	2	R_3, R_5	RESISTOR, CARBON COMP., 20Ω, 1/8W, 5%	ALLEN-BRADLEY	RC05GF200J
11.	1	R_4	RESISTOR, CARBON COMP., 200Ω, 1/8W, 5%	ALLEN-BRADLEY	RC05GF201J
12.	2	C_6, C_8	CAPACITOR, 1000 PF.	ERIE	RPA20NP0102J50N
13.	1	L_4	WIRE WOUND INDUCTOR	NRAO	A53201M013
14.	1	Q_2	FET	MITSUBISHI	MGF-1402
15.	1	R_6	RESISTOR, CARBON COMP., 75Ω, 1/8W, 5%	ALLEN-BRADLEY	RC05GF750J

PARTS LIST 327 MHZ, LOW NOISE, FET AMP DATE 10.20.86 REVISION

ITEM	QUANTITY	REF. DESIG.	DESCRIPTION	MFG.	PART NUMBER
16.	1	R_7	RESISTOR, CARBON COMP., 51Ω, 1/8W, 5%	ALLEN-BRADLEY	RC05GF510J
17.	1	R_8, R_{10}	RESISTOR, CARBON COMP., 130Ω, 1/8W, 5%	ALLEN-BRADLEY	RC05GF131J
18.	1	R_9	RESISTOR, CARBON COMP., 47Ω, 1/8W, 5%	ALLEN-BRADLEY	RC05GF470J
19.	1	IC_1	REGULATOR, VOLTAGE	NATIONAL SEMI COND.	78L05
20.	2	C_7, C_{11}	CAPACITOR .1uf	ERIE	RPE122Z5U104M100V
21.	1	D_1	DIODE, SI.	MOTOROLA	1N5060
22.	1	C_{14}	CAPACITOR, FEED-THRU 1000PF	SPECTRUM CONTROL	FB3B102W
23.	2	FB_1, FB_2	CORE, TOROID	MICROMETALS	T10-6
24.			SOLDER, 2% SILVER	ERSIN	SN62
25.			FLUX, ROSIN LIQUID	KESTER	#1544
26.			Q-DOPE, POLYSTYRENE	GC ELECTRONICS	CAT. NO. 37-2
27.			AMPLIFIER SCHEMATIC	NRAO	B53201S001
28.			CHASSIS, 327 MHZ.	NRAO	A53201M001
29.			CONNECTOR, REWORK	NRAO	A53201M003
30.			RAIL	NRAO	A53201M002

PARTS LIST 327 MHZ, LOW NOISE, FET AMP DATE 10·20·86 REVISION

ITEM	QUANTITY	REF. DESIG.	DESCRIPTION	MFG.	PART NUMBER
31.			DRAWINGS, DRILL	NRAO	A53201P001
32.	1		CHASSIS	COMPAC	#RS1170-075-1
33.			DRAWING, COMPONENT LAYOUT	NRAO	A53201M013
34.			ARTWORK, P.C. BOARD	NRAO	A53201Q001
35.			LOGO	NRAO	A53201I001
36.	1		LUG, GROUND, 1/4" DIA.	H. H. SMITH	#1468
37.	8		2-56 x 3/16" SOCKET HEAD CAP SCREWS S.S.	ALL-METAL SCREW PRODUCTS	
38.	8		2-56 x 1/4" SOCKET HEAD CAP SCREWS S.S.	ALL-METAL SCREW PRODUCTS	
39.	4		2-56 x 1/4" FLAT HEAD SCREWS, S.S.	ALL-METAL SCREW PRODUCTS	
40.	1	J_1	CONNECTOR, SMA INPUT	OMNI-SPECTRA	OSM-214CC
41.	1	J_2	CONNECTOR, SMA OUTPUT	OMNI-SPECTRA	OSM-204CC
42.			COMPONENTS (610 MHZ FET)	NRAO	A53201M014
43.	1		610 MHZ. AMPLIFIER SCHEM.	NRAO	B532025001